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(54) Third stage separator system  
for fluidised catalytic cracking  
unit in oil refining, and method of  
operating same

(57) The third stage gas/particle  
separator vessel of a fluidised cata-  
lytic cracking unit has its cyclone  
separators 2 discharging directly  
onto a collecting hopper floor 11 of  
the vessel 1 and the discharged  
particles continuously transfer under  
gravity from the collector hopper  
11 to a storage hopper 15 directly  
therebelow.

From time to time the storage  
hopper 15 is emptied by closing an  
isolation valve 14 between the col-  
lecting hopper 11 and the storage  
hopper 15 and then firstly venting  
the storage hopper 15 by opening a  
valve 24 and secondly opening an  
isolation valve 25 at the outlet of  
the storage hopper. Such a system

avoids the need for continuous  
bleed of gas through the particle  
outlet of the separator vessel 1.

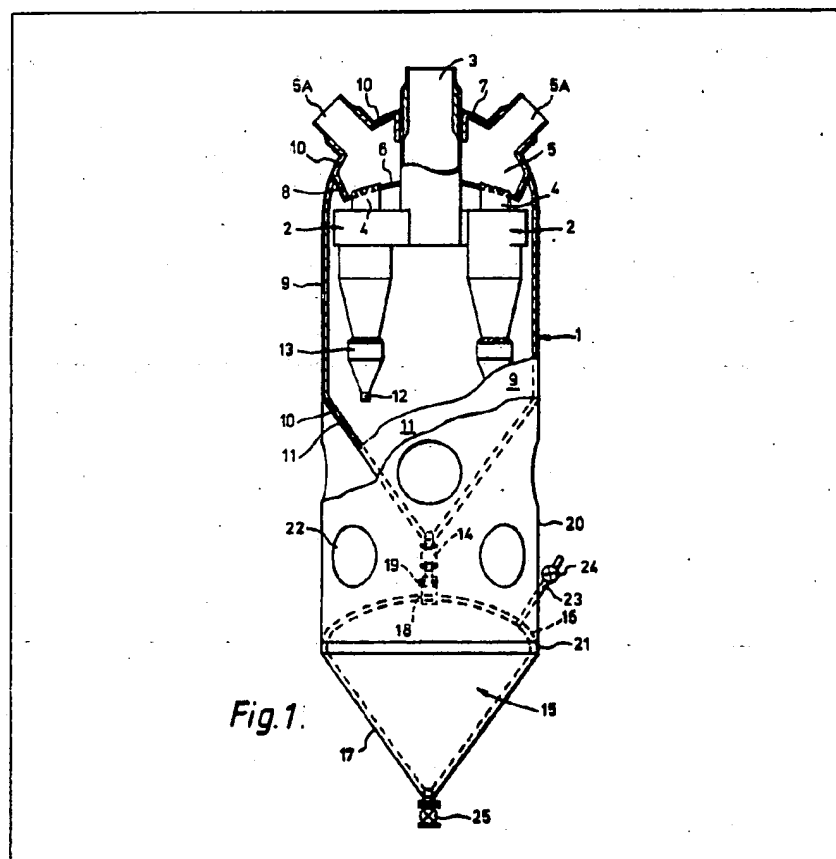


Fig. 1.

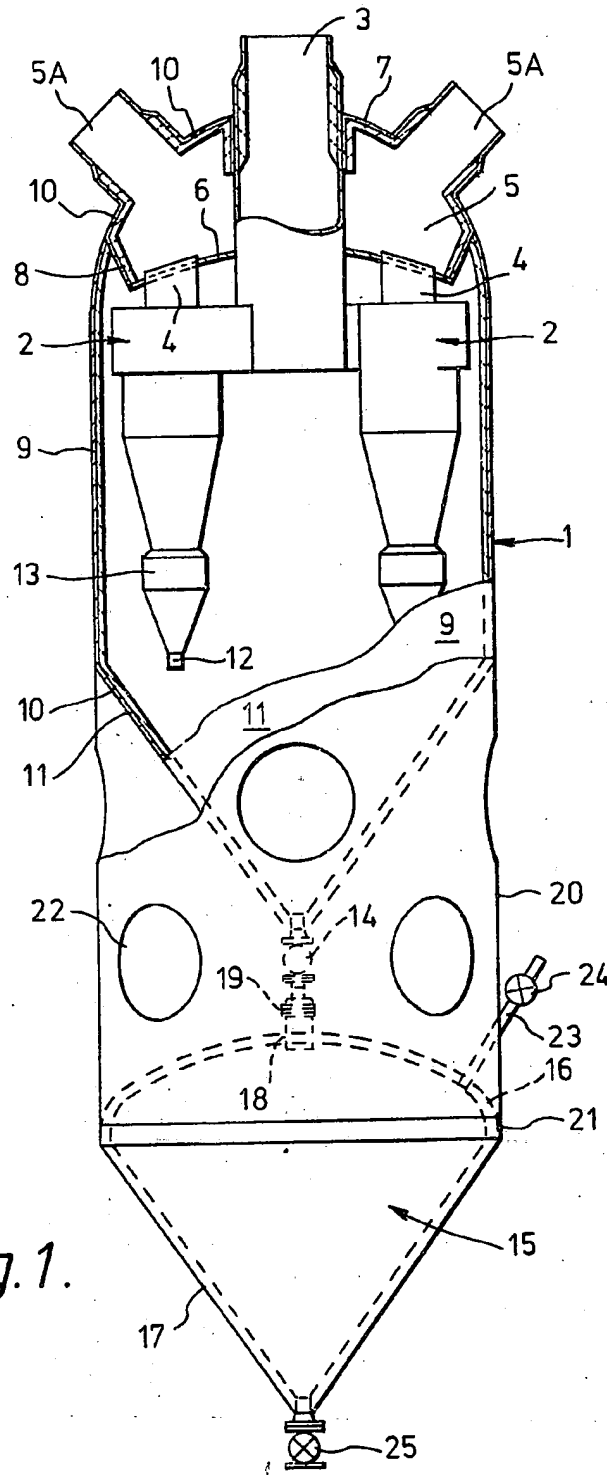
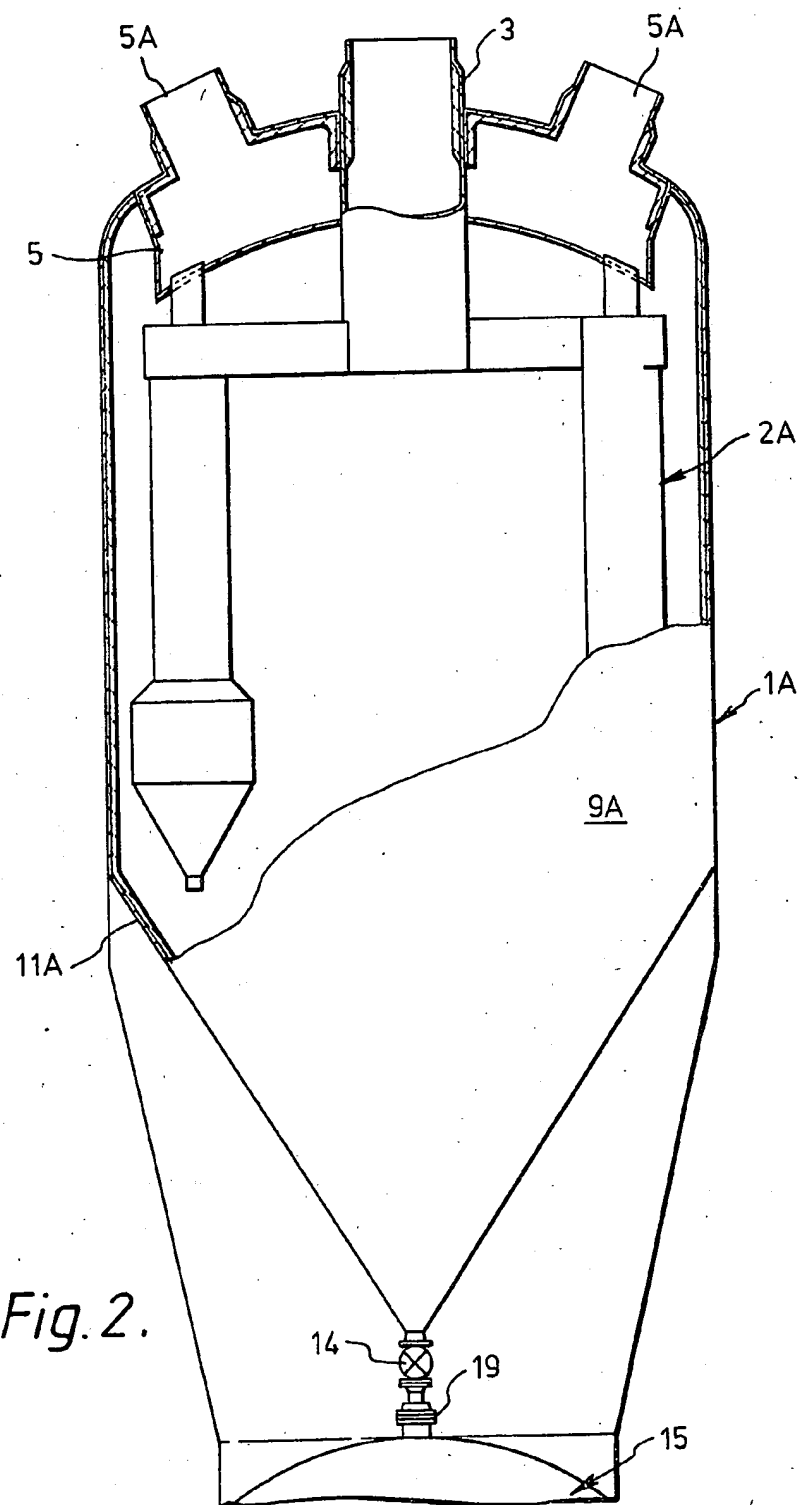


Fig.1.

2/2



## SPECIFICATION

**Third stage separator system for fluidised catalytic cracking unit in oil refining, and method of operating same**

The present invention relates to a modified form of third stage gas/particle separating unit for separating used catalyst particles from the gas discharged from a catalyst regenerator vessel in a fluidised catalytic cracking unit for oil refining. Such a system is commonly known as the third stage separating system.

Hitherto, it has been the practice for the particle-laden gas withdrawn from the gas outlets of cyclone separators in a fluidised catalytic cracking regenerator vessel to be introduced to the gas inlets of the cyclone separators of the third stage separating system from which the particles are then collected, normally for subsequent disposal because of their small size and adverse particle size distribution, and the gas is discharged to the exhaust stack either directly or by way of a power recovery turbine or a waste heat boiler. A typical conventional third stage separator system may include a surrounding separator vessel containing a battery of cyclone separators whose particle outlets discharge into the separator vessel to be collected on the hopper-shaped floor of that vessel. The particles then pass by way of a pneumatic conveying pipe in an upward direction from the collecting hopper floor of the third stage vessel which is just above ground level to a fourth stage cyclone separator from which the gas can be discharged directly to the exhaust stack and the recovered particles can be discharged into a separate storage hopper for subsequent clearance when the build-up of particles in the storage hopper requires it.

In the design and construction of third stage vessels for fluidised catalytic cracking units it has long been desirable to avoid excessively tall vessels, and it is for this reason that the floor of the third stage vessel is just high enough above the ground to allow for inlet to the onward particle conveying system to be disposed beneath the floor and just above the ground level; the battery of cyclone separators with their gas/particle inlet ducting, and frequently with a plenum chamber gas outlet, are arranged at the top of the third stage vessel and have dip legs extending down to a location just above the collecting hopper formation at the bottom of that third stage vessel. The conveying system is then expected to be capable of raising the particles to the level of the fourth stage cyclone separator which is high enough to allow a storage hopper to be placed therebelow, with provision for removal of particles from the storage hopper (for example into a waiting tank or vehicle).

According to the present invention, we pro-

vide a third stage gas/particle separator system for a fluidised catalytic cracking unit in oil refining, comprising a third stage separator vessel; a plurality of cyclone separators

mounted in said vessel and discharging into the vessel near the bottom thereof; an inlet for introducing a particle-laden gas to said cyclone separators; an outlet for discharging substantially particle-free gas from said cyclone separators and out of said third stage separator vessel; a storage hopper immediately below said third stage separator vessel; and air lock forming means controlling the flow of solids from said third stage separator vessel into said storage hopper for permitting clearance of a build-up of solids from said storage hopper without continuous gas escape from said third stage separator vessel.

The present invention also provides a method of operating a third stage gas/particle separator unit for a fluidised catalytic cracking unit in oil refining, comprising introducing particle-laden gas from a catalyst regenerator vessel into a third stage separator vessel including a plurality of cyclone separators; separating the particles from the gas in the cyclone separators, discharging the gas from said cyclone separators by way of a gas outlet for substantially particle-free gas; discharging the separated particles from said cyclone separators onto the floor of said third stage separator vessel; continuously transferring said particles under gravity to a closed storage hopper directly below the floor of said third stage separator vessel; periodically at least partially clearing said storage hopper by isolating said storage hopper from said third stage separator vessel, then venting said storage hopper to reduce the pressure therewithin, and finally opening said storage hopper to allow the build-up of catalyst particles in said storage hopper to be discharged without any continuing loss of gas from said third stage separator vessel; and, after clearing the storage hopper, resuming normal transfer of separated particles from said third stage separator vessel to said storage hopper after closing said vent and closing said discharge outlet of said storage hopper and then re-establishing communication between said third stage separator vessel and said storage hopper.

By incorporating the storage hopper directly below the chamber of the third stage separator vessel to form an integrated structure therewith, it is possible to simplify the equipment considerably by avoiding the need for a special conveying system to lift the separated particles to the location of a fourth stage cyclone separator. However, in view of the conventional desire to avoid excessively high third stage vessels it is advantageous to use the so-called "short cone" type of cyclone separator. More advantageously these cyclone separators are devoid of dip legs and discharge directly onto the collecting hopper

floor of the third stage vessel.

Desirably, the cyclone separators of the third stage may be free of individual collecting hoppers or so-called "disengagement hoppers" and may thus be even shorter in order to reduce the height of the third stage vessel by as much as possible.

In operating the method in accordance with the present invention, it is preferred that the outlet from the collecting hopper formation of the third stage separator vessel has a first isolation valve closing off the inlet to the storage hopper immediately therebelow, and the storage hopper itself has a second isolation valve such that these two valves constitute the air lock forming means and can be operated in such a way that the first isolation valve will normally be open but that when the hopper is to be emptied the said first valve is closed, and the storage hopper is vented before the second valve is opened to allow controlled discharge of the particles in the storage hopper under gravity, through said second valve.

In order that the present invention may more readily be understood the following description is given, merely by way of example, with reference to the accompanying drawings in which:—

Figure 1 is a schematic side elevation, partly in section, of a third stage separating system for a fluidised catalytic cracking unit in oil refining; and

Figure 2 is a view which is similar to Fig. 1 but depicts an alternative embodiment of the third stage system.

Fig. 1 shows a third stage separating vessel 1 including a plurality of third stage cyclone separators 2 therewithin, with the inlets to the separators connected to a main inlet duct 3 and their gas outlets 4 leading to a plenum chamber 5 at the upper part of the third stage vessel.

The floor 6 of the plenum chamber 5 provides structural support for the cyclone separators 2 by having their gas outlet necks 4 welded thereto. The roof 7 and the radially outer side wall 8 of the plenum chamber have an inner refractory lining 10, as does also the side wall 9 of the third stage vessel 1.

The design of the plenum chamber floor 6 and side walls 8 is in this case in accordance with the arrangements disclosed and claimed in our co-pending British Patent Application No. 8013092.

The floor 11 of the third stage vessel 1 is also provided with a refractory lining 10 on its inside, and is of conical form to define a collecting hopper portion of the third stage vessel. As can be seen in Fig. 1, the stub pipe 12 at the foot of the collecting hopper (often called a "disengagement hopper") 13 of the cyclone separator 2 is positioned level with the upper rim of the conical collecting hopper floor 11 of the third stage vessel, so that

particles separated in the cyclone separator 2 fall directly onto the collecting hopper floor 11.

At the downwardly disposed vertex of the conical floor 11 is a first isolation valve 14 which controls movement of the particles collected on the collecting hopper floor 11 down into a storage hopper 15 directly therebelow.

The storage hopper 15 has a refractory-lined, domed ceiling 16 and a conical refractory-lined hopper portion 17, and has its inlet 18 connected to the above-mentioned first isolation valve 14 by means of an expansion joint 19 to allow for thermal deformation of the vessel 1 as the apparatus heats up from a "cold" condition to an "operating" condition at which the inlet gas stream flowing along the duct 3 into the cyclone separators 2 can be at a temperature in the region of 730°C. The storage hopper has at its lowest point (the vertex of the cone) a second isolation valve 25.

For structural integrity of the unit comprising the third stage vessel 1 and the storage hopper 15, a cylindrical skirt 20, in this case having a thickness less than that of the wall 9 of the third stage vessel 1 itself, extends downwardly from the bottom of the side wall of the vessel 1 and is welded at the region 21 where the domed ceiling 16 of the discharge hopper joins the conical hopper portion 17 thereof. Because the skirt 20 does not define the wall of a pressure-tight vessel (given that the underside of the conical collecting hopper floor 11 of the third stage vessel 1 is no longer at the same pressure as the interior of the vessel 1), the skirt 20 includes a plurality of circular apertures 22 which enable the weight of the skirt 20 to be reduced and also allow for access to the first isolation valve 14 and the expansion joint 19.

As also shown in Fig. 1, the domed ceiling 16 of the storage hopper 15 includes a vent pipe 23 provided with a third isolation valve 24 which can be operated when the hopper 15 is to be cleared. The vent pipe 23 may be connected to the floor of the storage hopper 15, if required, but it must be at a level above the expected level of the top of the particle build-up in the storage hopper. Connecting it to the ceiling 15 is therefore preferred.

The operation of the third stage particle/gas separating system in accordance with the present invention is as follows:—

The gas outlet stream from the cyclone separators in the catalyst regenerator vessel (not shown) enters the inlet duct 3 at a temperature of around 730°C and the gas still contains some catalyst particles but mainly the finer fractions of those particles which are not of any great value for recycling to the fluidised catalytic cracking reactor vessel.

The high temperature particle-laden gas passes from the duct 3 into the individual cyclone separators 2 and forms a coaxial

vortex in each of the cyclone separators 2 so that the cleaned gas passes upwardly into the plenum chamber 5 while the separated catalyst particles fall downwardly through the stub pipe 12 and onto the conical collecting hopper floor 11 of the third stage vessel 1.

The action of the disengagement hopper 13 at the bottom of each cyclone separator 2 is to allow a sudden increase in the diameter of the cyclone separator with the result that the dust entrained in the vortex can move radially outwardly away from the core of the vortex and thereby enhance the separating effect.

The height of the third stage separating vessel 1 can be reduced still further if the collecting hoppers or "disengagement hoppers" 13 are eliminated and the bottom cone of the cyclone separator allowed to discharge straight to the gas space within the vessel 1. The sudden transition of the particles at the bottom of the vortex into the much larger cross section vessel 1 serves to carry out the "disengagement" function, releasing the particles into the vessel 1 and allowing the gas to be entrained upwardly along the core of the vortex towards the gas outlet of the cyclone separator.

The first isolation valve 14 will normally be open so that the separated catalyst particles pass through the valve 14 and the expansion joint 19 and down into the storage hopper 15 by way of its inlet 18. The second isolation valve 25 is normally closed and so is the third isolation valve 24 in the vent line 23 and thus there will be no net movement of gas through the first discharge valve 14 once the storage hopper 15 has become pressurised. However, particles will build up in the bottom of the storage hopper 15 and will, to some extent, displace gas upwardly back into the third stage vessel 1.

When the build-up of particles in the storage hopper 15 is expected to have achieved a magnitude at which it is propitious to clear the discharge hopper 15, the first isolation valve 14 is closed to isolate the storage hopper 15 from the collecting hopper 11 of the third stage vessel 1. Further delivery of particles from the stub pipes 12 of the cyclone separators 2 causes a build-up on the collecting hopper floor 11.

Now that the storage hopper 15 has been isolated from the pressurised third stage vessel 1, the vent pipe 23 is communicated to atmosphere, by opening the third isolation valve 24, and the gas under pressure in the storage hopper 15 is allowed to escape to atmosphere.

If desired, a small scale cyclone separator may be incorporated in the vent pipe 23 downstream of the third isolation valve 24, so as to clean up the vented air of any residual catalyst particles as an environmental anti-pollution precaution.

As soon as the pressure in the storage

hopper 15 has reduced to atmospheric pressure, and a suitable container (for example a tanker vehicle) has been positioned below the second isolation valve 25, the valve 25 can be opened to allow controlled emptying of the storage hopper 15 under gravity.

Once enough of the catalyst particles have been discharged through the second isolation valve 25, the valve 25 can be closed and so also will the third isolation valve 24 be closed and then the first isolation valve 14 from the collecting hopper 11 can be re-opened to allow re-pressurisation of the storage hopper 15 and transfer of the collection of particles resting on the collecting hopper floor 11 down through the isolation valve 14 and into the storage hopper 15.

The first, second and third isolation valves 14, 25 and 24 thus constitute an air lock forming means which allow the cyclone separators 2 in the third stage vessel 1 to continue operating without any gas bleed-off, other than by way of the gas outlet plenum chamber 5, even when the storage hopper 15 is vented to atmosphere and is being emptied.

In Fig. 1, in order to reduce the height of the third stage vessel 1 and its associated storage hopper 15, the particular design of cyclone separator 2 employed in this embodiment is the so-called "short cone" separator. Such a separator has a conical portion having a ratio of cone length to cyclone body diameter of 4:3 or thereabouts. To reduce the size of the cyclone separator and hence the third stage vessel still further, it may be employed at a gas inlet velocity of 30 m/s or more, but operating experience has shown that conventional cyclones of either normal or short cone length require erosion resistant refractory lining which involves its own disadvantages. For example, each cyclone separator 2 shown in Fig. 1 has a refractory lining of approximately 19 mm thickness. The outlet pipes 5a from the plenum chamber 5 may be connected either directly to the exhaust stack or to a power recovery turbine and/or waste heat boiler through which the gas passes before being discharged by way of the stack.

In conventional third stage catalyst separator systems there is a continuous bleed of gas from the third stage vessel in order to facilitate flow of the separated catalyst particles into and along the conveyor system which is then required to lift the particles to a level high enough to allow them to be separated from the gas flow in a fourth stage cyclone separator which has its particle outlet feeding the storage hopper. In this conventional arrangement, the storage hopper may be alongside the third stage separator vessel.

The embodiment proposed in Fig. 1 has the advantage that because the second and third isolation valves 25 and 24 will normally be closed and will only be opened once the first isolation valve 14 has been closed, there will

b no constant bleed of gas from the solids outlet of the third stage separator vessel 1 and consequently substantially all the particles delivered from the third stage vessel 1 will be in the form of solids to be discharged through the second isolation valve 25. With the previous third stage separator systems, all the catalyst particles separated by the third stage are conveyed by this gas bleed flow and require further separation. This separation which in the nature of things is less than 100% efficient, increases the overall loss of particles emitted to the atmosphere. Such separation is an optional feature on the vent pipe 23 in Fig. 1.

Fig. 2 shows an alternative embodiment of third stage gas/catalyst particle separator system in accordance with the present invention, and in which a different design of cyclone separator 2A has been used.

Whereas in Fig. 1 there were five "short cone" cyclone separators 2 in the vessel 1, the embodiment shown in Fig. 2 uses high aspect ratio cyclone separators of the kind disclosed and claimed in our British Patent Specification No. 1,528,658. Because of the entirely cylindrical body of these separators 2A, and the low gas inlet velocity employed, there is no need for an anti-erosion refractory lining in the cyclone separators and the cyclones can be fabricated from a steel appropriate to the gas conditions. For example, Austenitic steel may suffice. The number of separators can be varied at will and may for example be eight, or ten, or sixteen, but any other number may be chosen to suit the operating conditions.

The advantage of using a number of high aspect ratio cyclone separators 2A higher than the number of "short cone" cyclone separators 2 in Fig. 1 is that the pressure drop in the third stage recovery vessel is less in Fig. 2 than it would be in Fig. 1, and this is a particularly important characteristic where the discharge pipes 5A of the plenum chamber 5 are to feed the exhaust gas to a power recovery turbine.

Such a power recovery turbine may, for example, provide all the energy requirements for feeding combustion air to the burners of the catalyst regenerator vessel.

Although only the third stage separator vessel 1A is shown in Fig. 2, it will be understood that the storage hopper 15 below the vessel 1A is of the same form and operates in the same way as the storage hopper 15 of Fig. 1.

Because the high aspect ratio cyclone separators 2A of Fig. 2 no longer require anti-erosion refractory linings, they can be relied upon to give much less risk of solids carry-over into a power recovery turbine (where fitted) and consequently this particular embodiment is much better suited for connecting to a downstream recovery turbine. Any refrac-

tory-lined cyclone separator is open to the risk of refractory material breaking away from the lining, in use of the separator. This has not only the disadvantage of the risk of turbine blade damage if this loose refractory material carries over into the turbine, but also the consequence that the resulting cavities appearing in the refractory lining of the cyclone separators could give a loss of cyclone separating efficiency. The repeated temperature cycling as the apparatus is heated up and cooled down will cause inevitable deterioration of the refractory lining, with the high risk of solids carry-over.

The embodiment of Fig. 2 is well suited for an "environmental clean-up" application where the separating efficiency is not affected by the possibility of deteriorating linings, and thereby ensures always that a minimum of catalyst is discharged into the atmosphere by way of the exhaust stack from the outlets 5A.

It has been conventional, in the design of third stage gas/catalyst separating systems, using cyclone separators contained in a vessel, to include a dip leg as the solids outlet means of the cyclone separator into the vessel. It is an important feature of the embodiments shown in Figs. 1 and 2 that no such dip legs are incorporated and consequently that the height of the separating vessel can be considerably reduced with respect to one in which dip legs are provided. Although a dip leg, or some analogous means for discharging the solids only under pressure, is conventional in the third stage vessel and is necessary for the cyclone separators of a catalyst regenerator vessel, we believe the dip leg is not necessary in the third stage vessel and we prefer to eliminate such a dip leg in order to enhance the geometrical characteristics of the third stage system in accordance with the present invention.

As mentioned above, the separating system in accordance with the present invention avoids the need for a gas bleed to transfer the dust to the storage hopper and/or fourth stage separator, and consequently the available power to be recovered for energy conservation is enhanced. Secondly the fact that the dust is allowed to settle in the collecting hopper portion at the bottom of the third stage separator vessel, to be transferred to the storage hopper under "airlock" conditions, will give rise to an increased overall separating efficiency of the system.

#### CLAIMS

1. A third stage gas/particle separator system for a fluidised catalytic cracking unit in oil refining, comprising a third stage separator vessel; a plurality of cyclone separators mounted in said vessel and discharging into the vessel near the bottom thereof; an inlet for introducing a particle-laden gas to said cyclone separators; an outlet for discharging

substantially particle-free gas from said cyclone separators and out of said vessel; a storage hopper immediately below said third stage separator vessel; and air lock forming means controlling the flow of solids from said third stage separator vessel into said storage hopper for permitting clearance of a build-up of solids from said storage hopper without continuous gas escape from said third stage separator vessel.

2. A system according to claim 1, wherein said air lock forming means includes a first isolation valve between an outlet from said third stage separator vessel and an inlet to said storage hopper, and a second isolation valve at an outlet from said storage hopper, the arrangement being such that when said second isolation valve is closed and said first isolation valve is open particles delivered from each said cyclone separator fall through said first valve and into said storage hopper, and that when said first isolation valve is closed and said second isolation valve is open, the build-up of solids in said storage hopper can be discharged without continual bleed of gas through the particle outlet of said third stage separator vessel.

3. A system according to claim 2, and including a vent pipe connected to a ceiling of said storage hopper and incorporating a third isolation valve in said vent pipe.

4. A system according to claim 3, and including an additional cyclone separator in said vent pipe downstream of said third isolation valve.

5. A system according to any one of claims 1 to 4, wherein said cyclone separators have no dip legs but discharge straight into the interior of said third stage separator vessel.

6. A system according to any one of the preceding claims, wherein said cyclone separators are the so-called "short cone cyclones".

7. A system according to claim 6, wherein said cyclone separators do not include individual collector hoppers.

8. A system according to any one of claims 1 to 5, wherein each said cyclone separator is a high aspect ratio cyclone separator including a cylindrical cyclone separator portion having a substantially uniform internal diameter.

9. A system according to claim 8, wherein each said cyclone separator is formed of steel and is without any additional anti-erosion lining.

10. A system according to any one of the preceding claims, wherein said gas outlet for substantially particle-free gas is connected directly to an exhaust stack.

11. A system according to any one of claims 1 to 9, wherein said outlet for substantially particle-free gas is connected to means for recovering energy therefrom.

12. A system according to claim 11,

wherein said energy recovering means includes a power recovery turbine.

13. A system according to claim 11 or 12, wherein said energy recovering means includes a waste heat boiler.

14. A system according to any one of the preceding claims, wherein said storage hopper and said third stage vessel are mounted one above another in an integrated structure.

15. A system according to claim 14, wherein said third stage vessel is cylindrical with a conical floor and said storage hopper is conical with a skirt joining the bottom of the cylindrical third stage vessel to the rim of the cone of said storage hopper.

16. A method of operating a third stage gas/particle separator unit for a fluidised catalytic cracking unit in oil refining, comprising introducing particle-laden gas from a catalyst regenerator vessel into a third stage separator vessel including a plurality of cyclone separators; separating the particles from the gas in the cyclone separators, discharging the gas from said cyclone separators by way of a gas outlet for substantially particle-free gas; discharging the separated particles from said cyclone separators onto the floor of said third stage separator vessel; continuously transferring said particles under gravity to a closed storage hopper directly below the floor of said third stage separator vessel; periodically at least partially clearing said storage hopper by isolating said storage hopper from said third stage separator vessel, then venting said storage hopper to reduce the pressure therewithin, and finally opening said storage hopper to allow the build-up of catalyst particles in said storage hopper to be discharged without any continuing loss of gas from the said third stage separator vessel; and, after cleansing the storage hopper, resuming normal transfer of separated particles from said third stage separator vessel to said storage hopper after closing said vent and closing said discharge outlet of said storage hopper and then re-establishing communication between said third stage separator vessel and said storage hopper.

17. A third stage separator system for a fluidised catalytic cracking unit in oil refining, substantially as hereinbefore described with reference to and as illustrated in Fig. 1 or Fig. 2 of the accompanying drawings.

18. A method of operating a third stage gas/catalyst separator system in a fluidised catalytic cracking unit for oil refining, substantially as hereinbefore described with reference to Fig. 1 of the accompanying drawings.

## 125 CLAIMS (28 Apr 1981)

1. A third stage gas/particle separator system for a fluidised catalytic cracking unit in oil refining, comprising a third stage separator vessel; a plurality of cyclone separators mounted in said vessel and having a solids



discharge opening into the vessel near the bottom thereof but above the upper level of a bed of separated solids which, in use of the system, builds up at the bottom of the vessel;  
 5 an inlet for introducing a particle-laden gas to said cyclone separators; an outlet for discharging substantially particle-free gas from said cyclone separators and out of said vessel; a storage hopper immediately below said third stage separator vessel; and air lock forming means between said vessel and said storage hopper for controlling the flow of said separated solids from said third stage separator vessel into said storage hopper for permitting  
 10 clearance of said bed of solids from said storage hopper without continuous gas escape from said third stage separator vessel.

5. A third stage gas/particle separator system for a fluidised catalytic cracking unit in oil refining, comprising a third stage separator vessel; a plurality of cyclone separators mounted in said vessel and discharging directly onto the vessel near the bottom thereof without the use of dip legs; an inlet for  
 25 introducing a particle-laden gas to said cyclone separators; an outlet for discharging substantially particle-free gas from said cyclone separators and out of said vessel; a storage hopper immediately below said third stage separator vessel; and air-lock forming means controlling the flow of solids from said third stage separator vessel into said storage hopper for permitting clearance of a build-up  
 30 of particles from said storage hopper without continuous gas escape from said third stage separator vessel.

16. A method of operating a third stage gas/particle separator unit for a fluidised catalytic cracking unit in oil refining, comprising  
 40 introducing particle-laden gas from a catalyst regenerator vessel into a third stage separator vessel including a plurality of cyclone separators; separating the particles from the gas in the cyclone separators, discharging the gas from said cyclone separators by way of a gas  
 45 outlet for substantially particle-free gas; discharging the separated particles from said cyclone separators onto the floor of said third stage separator vessel through particle outlets disposed above the upper level of the bed of  
 50 separated particles built upon the bottom of the separator vessel in use of the system; continuously transferring said particles under gravity to a closed storage hopper directly below the floor of said third stage separator  
 55 vessel; periodically at least partially clearing said separated particles from the storage hopper by isolating said storage hopper from said third stage separator vessel, then venting said  
 60 storage hopper to reduce the pressure therein, and finally opening said storage hopper to allow the build-up of catalyst particles in said storage hopper to be discharged without any continuing loss of gas from the  
 65 said third stage separator vessel; and, after

cleansing the storage hopper, resuming normal transfer of separated particles from said third stage separator vessel to said storage hopper after closing said vent and closing said  
 70 discharge outlet of said storage hopper and then re-establishing communication between said third stage separator vessel and said storage hopper

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